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<u>HEVEA DISEASES OF THE WESTERN HEMISPHERE</u>

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The Plant Disease Reporter is issued as a service to plant pathologists throughout the United States. It contains reports, summaries, observations, and comments submitted voluntarily by qualified observers. These reports often are in the form of suggestions, queries, and opinions, frequently purely tentative, offered for consideration or discussion rather than as matters of established fact. In accepting and publishing this material the Section of Mycology and Disease Survey serves merely as an informational clearing house. It does not assume responsibility for the subject matter.

PLANT DISEASE REPORTER SUPPLEMENT

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THE PLANT DISEASE SURVEY
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CONTENTS

HEVEA DISEASES OF THE WESTERN HEMISPHERE

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The Hevea rubbertree (Hevea brasiliensis) is native to the jungles of South America. For many years prior to 1910, these jungle trees supplied the bulk of the world's rubber. On these scattered trees growing in their native habitat, disease damage usually was limited and generally passed unnoticed. When large numbers of Hevea trees were brought together in plantations, however, the opportunities for disease spread and build-up increased greatly. Disease control then became a problem of the utmost importance.

The United States Department of Agriculture, in cooperation with commercial companies and the governments of most tropical American countries, since 1940 has carried on a program of research and investigation basic to the development of rubber production in the Western Hemisphere. As new plantings have been established in widely scattered parts of the American Tropics, the major disease problems of the Hemisphere have come to light. It is now known that certain diseases that are serious in some areas cause no appreciable damage in others. All told, there are seven or eight diseases that have proved destructive enough to warrant control measures in one or more areas. The major disease problems of the rubber-growing industry of the Far East are different from those encountered in the American Tropics and are not discussed in this article.

South American Leaf Blight

South American leaf blight is not so well known as chestnut blight but is comparable to it in destructiveness. South American leaf blight of Hevea is endemic in the Amazon Valley and has spread as far south as the State of Bahia in Brazil and as far north as the State of Oaxaca in Mexico. It is now found in Brazil, Colombia, Bolivia, Peru, and the Guianas in South America; in Panama, Costa Rica, Nicaragua, and Guatemala in Central America; in Mexico; and in the island of Trinidad. The history of South American leaf blight and the methods by which it is now controlled are given in a separate article by M. H. Langford and C. H. T. Townsend, Jr.

Phytophthora Pod Rot, Leaf Fall, Dieback, and Panel Decay

Phytophthora pod rot, leaf fall, dieback, and panel decay are symptoms of attack by a single fungus, Phytophthora palmivora. It has a wide host range. Cacao pod rot, of considerable economic importance, is caused by this same fungus. Hevea is attacked, at least sporadically, in most rubber-growing areas of the American Tropics. Serious damage from leaf fall and dieback occurs only under extremely humid conditions. The panel phase of the disease requires attention throughout the rainy season in some areas.

In Hevea plantings in which leaf blight has been controlled by use of resistant clones, Phytophthora often becomes the most troublesome disease. Extreme susceptibility to this disease has precluded further use in some localities of several blight-resistant clones that otherwise were highly suitable as crown clones. During the exceptionally wet weather of 1950-1951, a period of eight months, for example, the disease caused complete defoliation and extensive dieback in some Hevea plantings on the Atlantic Coastal Plain of Costa Rica. At Belterra Estate in Brazil, a limited amount of leaf fall occurs during the rainy season of each year, but the disease becomes inactive during the long dry season. Severe dieback and death of trees has occurred only in certain clones of Hevea benthamiana at Belterra. So far, those are the only localities from which serious outbreaks have been reported.

Leaves of any age may be attacked by Phytophthora. When young leaves are attacked, they may become blackened and shriveled, presenting an appearance similar to that caused by fire damage. On mature leaves, the lesions are inconspicuous but a single one may cause the leaf to drop.

Dieback is usually limited to young shoots and twigs but in some cases major branches, or even the entire crown, may be killed.

The panel phase of the disease is commonly known as black stripe or patch canker. This phase is initiated by an attack of the fungus on the tapping cut or other injuries. The decayed area may cover only a few square inches or it may involve the greater portion of the trunk. Severe cases of black stripe or patch canker may require suspension of tapping for prolonged

periods.

Phytophthora damage in some areas is very limited and the disease requires no special control measures. Resistant or tolerant clones should be used in other areas to guard against excessive leaf fall and dieback.

Studies of resistance to Phytophthora are still in an early stage. A small percentage of the Hevea clones growing at the Rubber Plant Substation, of the Department of Agriculture, Los Diamantes, Guapiles, Costa Rica showed remarkably little damage from leaf fall and dieback through months of extremely wet weather in 1950-1951. The progenies of crosses between Hevea brasiliensis and certain H. benthamiana clones were especially promising and are being tested further.

Control of panel decay caused by Phytophthora is now under investigation in Brazil and Cost Rica. Incidence of this phase of the disease can be reduced by opening new panels only during the driest months of the year.

Target Leaf Spot

Target leaf spot, caused by Pellicularia filamentosa, is at present an important disease only in Peru and Brazil. It could also become troublesome in the Amazonian lowlands of Bolivia and Colombia, should Hevea plantations be established there. This fungus disease is confined to the leaves and causes damage by defoliation during the rainy season. Repeated defoliations retard the growth and reduce the vigor of young plants. Prolonged dry weather promptly and effectively controls the disease.

Target spot is worst as a nursery disease. It limits, or prevents, the successful budgrafting of seedling stocks and reduces the amount of usable budwood in clone-multiplication gardens. When seedlings develop to the first flush stage in seed beds prior to transplanting, the disease can cause severe damage and may assume the appearance of a web blight. Target spot may also retard the growth of field-planted trees until they have developed a crown of foliage and have undergone several annual leaf changes.

Target spot lesions range up to 2 inches in diameter and usually are zonate. They are covered on the under side by a network of silvery fungus threads. The disease is spread by enormous numbers of wind-borne spores. To a large extent, these are produced at night when conditions for infection are most favorable.

Target spot is most satisfactorily controlled with Dithane (Z-78). Lacking this material, it may be controlled with any of several fungicidal sprays, including the fixed or insoluble coppers or organic fungicides such as Spergon and Fermate. Target spot ordinarily is controlled by the spray program required for leaf blight. Otherwise, applications at 4- to 7-day intervals may be needed to reduce leaf infection and give satisfactory control of leaf fall.

Control through disease resistance has not yet been obtained. Some of the blight-resistant, top-budding clones, however, are quite tolerant to target spot and make fair growth even under severe disease conditions. Selections from a number of species of Hevea other than H. brasiliensis have shown varying degrees of resistance to the disease. Through hybridization, therefore, target-spot resistance may eventually be incorporated into commercial clones.

Diplodia Infection of Buddings

Infection of Hevea buddings by the fungus Diplodia theobromae is often the major cause of budding failure. This fungus has been troublesome in each of the countries in South and Central America, and in Mexico, where rubber culture has been undertaken. At times, it reduces the percentage of budding success to disastrously low levels. If the budding is done during periods unfavorable for the growth of the rubbertree, the infection may also kill the cambium beneath the budpatch and even spread into the surrounding bark.

Budding is required in the commercial propagation of Hevea to insure high yields. It is also practiced in this Hemisphere to graft blight-resistant tops on high-yielding panel clones. Satisfactory budding success is essential to the economic establishment of Hevea plantings.

Control of budpatch infection has been obtained with a fungicidal treatment using Fermate, which is toxic to Diplodia and nontoxic to the cambium of Hevea. The Fermate is mixed with water at a concentration of 200 grams per liter (6.7 ounces per quart). Before cutting the budpatches, the stick of budwood is wiped with a cloth moistened with the fungicidal preparation and allowed to dry, leaving a film of fungicide on the bark. The budding panels on the stock plants are cut in the usual manner and the exuded latex is allowed to coagulate. Then the fungicidal-moistened cloth is used to wipe off the coagulated latex and at the same time leave a

protective coating of the fungicide in the cuts and around the marked-out panel. From this point on, the usual budding technique is followed; that is, flap opened or pulled off, budpatch inserted, and budding wrapped.

In addition to attacking buddings, Diplodia is commonly encountered as a weak parasite in connection with sunscald of the trunk and with dieback of branches weakened by leaf blight. Infection of budwood by Diplodia can be a serious factor in shortening the life of budwood being shipped from one country to another. This is especially true if the budwood loses vitality owing to a considerable lapse of time before use, exposure to unfavorable temperatures, or loss of moisture. Treatment with 20% Fermate before shipment is recommended to check deterioration.

Root Diseases

Root diseases occur in most rubber-growing centers of the Hemisphere but damage has been much lighter than that reported from many areas of the Far East. White root disease and brown root disease have accounted for most of the losses in field plantings. The Helicobasidium root disease has caused losses in nurseries, in some areas.

White root disease, caused by Fomes lignosus, has caused limited damage to Hevea plantings in widely separated parts of the Hemisphere. It has occurred most commonly in Costa Rica and Mexico.

Fomes lignosus attacks the roots of many kinds of trees. When jungle land is cleared, the fungus may continue to live on the roots that remain in the soil. It may infect the roots of young rubbertrees that come in contact with diseased jungle tree roots.

The fungus spreads along an infected root by means of small threads, or rhizomorphs, which may form a white network over the root - hence the name "white root disease".

Wilting of the foliage and branch dieback usually are the first aboveground symptoms of root disease. Eventually, the tree dies or is blown over by the wind.

A disease that causes symptoms characteristic of brown root disease has occurred in field plantings at Belterra Estate in Brazil for many years. In the absence of fruiting structures for a definite determination, the causative fungus is tentatively referred to Fomes noxius. Brown root disease differs from white root disease in that its rhizomorphs form a blackish, rather than a whitish, crust. Also, they usually bind a covering of soil to the infected roots.

Losses from brown root disease have been small, usually not exceeding a few hundred trees annually out of approximately 2 million at Belterra. Recently a root disease, which appears to be the same as that occurring at Belterra, has killed approximately 1 percent of the six-year-old trees in some blocks in a Hevea planting at Belém, Brazil. The incidence of disease is less in younger areas. This disease is now being investigated at Brazil's Instituto Agronomico do Norte. Initial inoculation trials there have indicated that the disease has a low order of transmissibility.

In most rubber-growing areas of the Western Hemisphere, the incidence of root disease has not been high enough to warrant control measures.

Moldy Rot

Moldy rot, caused by Ceratostomella fimbriata, is one of the most serious tapping-panel diseases of Hevea rubbertrees in the Far East. It has caused serious damage in plantations of old Hevea trees in southern Mexico but has not yet become a problem in other areas of this Hemisphere. W. J. Martin, formerly pathologist of the United States Department of Agriculture, has investigated moldy rot and the means of controlling it.

Moldy rot develops rapidly on tapped bark and other wounds and may penetrate both above and below injured areas under conditions of high humidity. Decay of the soft bark and cambial regions hinders bark renewal. In severe cases, this may prevent tapping of the trees after the original bark has been used.

Control of moldy rot was not attained by fungicidal treatments under the nearly ideal conditions for disease development encountered in old plantations in Mexico. Exclusion of the disease from new plantings and attempts to eradicate it when first observed are recommended procedures.

Pink Disease

Pink disease, caused by Corticium salmonicolor, has been noted in many widely-scattered Hevea plantings in this Hemisphere. The fungus has a very wide host range; therefore, distribution over a wide area is to be expected. It has caused damage in some Hevea plantings on the west coast of Guatemala but has attacked only a fraction of 1 percent of the trees in plantings of most other areas. In no case has it caused damage approaching that reported from rubber estates in the Far East.

Attacks of pink disease are usually confined to trees between the ages of two and ten years. Infections most often occur at, or near, a fork. Both the central stem and the branches emerging at the fork may be attacked. A pink incrustation over the affected area distinguishes pink disease from any other disease of Hevea.

The old method of treating pink disease is by excision and burning of all diseased parts of the tree. A major portion of the crown is usually lost as a result of this treatment. Recent work shows that most attacked stems and branches recover without treatment. Painting over the infected area with a coal tar preparation or other disinfectant may reduce inoculum.

Glomerella Dieback

Glomerella dieback, caused by Glomerella cingulata, is one of the most prevalent Hevea diseases of the lower Amazon Valley. It occurs in a number of other areas but has not caused appreciable damage in most of them. The imperfect stage of the fungus, the one that is commonly found, is Colletotrichum gloeosporioides.

The fungus may cause rim blight of leaves as well as dieback. The greatest damage is done to young shoots, which are usually attacked at the nodes. Decay sets in and the shoot may break off while its leaves are still green. This distinguishes the disease from Phytophthora dieback, which usually kills the upper part of the flush first.

Severe attacks of Glomerella dieback are largely confined to trees that are not in a vigorous state of growth. The underlying cause of poor growth may be poor soil, inadequate drainage, an excessively dense stand, or other factors. All indications are that the prevalence of Glomerella dieback in the lower Amazon Valley is largely attributable to poor soil. An application of N-P-K fertilizer gave striking reductions in disease incidence in Hevea plantings at both Belém and Belterra, Brazil.

Black Crust

Black crust, caused by Catacauma huberi, occurs only in South America and is confined largely to the Amazon basin. It is one of the most conspicuous and least destructive of all Hevea diseases.

Only young leaves can be infected by black crust. The fungus develops very slowly in the leaf. Visible lesions seldom, if ever, appear on leaves that are less than a month old. The lesions gradually increase in size and may attain a diameter of 1 inch by the time the leaves are six to eight months old. Black crust seldom causes defoliation.

Black crust can be identified by the shining black incrustations that occur on the under side of infected leaves. The crusts are arranged in circles which often are separated by greenish zones.

An occasional clone appears to be extremely susceptible to black crust and may have a large percentage of its leaf area covered with lesions by the end of the rainy season.

The disease is not serious enough to warrant control measures other than avoidance of especially susceptible clones.

Periconia Blight

Periconia blight of Hevea, caused by Periconia heveae, has been reported from Costa Rica, Bahia and the Amazon region of Brazil, and from Mexico. It is not considered a leaf disease of major importance. However, in 1943, during a prolonged rainy period in Costa Rica, this disease reached epiphytotic proportions in a Hevea spruceana nursery and also produced minor damage in a nearby nursery of H. brasiliensis seedlings and budwood gardens. It has been seen on H. guianensis and H. benthamiana.

Lesions occur on both petioles and leaves. Leaf spots are circular to irregular and often are elongated along veins. Several may coalesce to involve an entire leaflet and may bring

about premature abscission. The spots are brown at first, becoming gray at the center with a brown border. The necrotic areas split irregularly and may fall away in part.

Leaves of all ages may be attacked, although greatest damage occurs to the youngest leaves. The disease frequently has followed South American leaf blight infections in areas where susceptible plants were growing. Periconia blight, which may be very destructive during prolonged periods of rainy weather, is reduced almost to the point of disappearance during the dry season.

Hevea spruceana, the most susceptible species, has only limited usage in the research program for production of hybrid seed and is not an important rubber-producing species of commerce. The fact that several *H. brasiliensis* clones, which are resistant to South American leaf blight, have been damaged by Periconia blight at Turrialba, Costa Rica, and elsewhere has alerted rubber pathologists to the possibilities of new outbreaks, even though all evidence to date indicates that it will not become a problem on the important rubber-producing species of commerce, *H. brasiliensis*.

FIELD CROPS RESEARCH BRANCH, AGRICULTURAL RESEARCH SERVICE, U. S. DEPARTMENT OF AGRICULTURE

CONTROL OF SOUTH AMERICAN LEAF BLIGHT OF HEVEA RUBBERTREES

M. H. Langford and C. H. T. Townsend, Jr.

South American leaf blight has long been recognized as the most destructive pest of the Hevea rubbertree. The causal organism of this disease is a fungus, Dothidella ulei. Under humid conditions, it may multiply rapidly and destroy the young foliage of Hevea trees. Trees of any age may be killed by successive defoliations.

Leaf blight seldom causes severe damage to scattered Hevea trees growing in their jungle habitat. However, when the trees are planted row upon row in nurseries or fields, the opportunities for disease development and spread are greatly increased. Thus, this disease, which had hardly been noticed when most of the world's rubber came from wild trees growing in the Amazon Valley, first presented a serious problem when attempts were made to grow Hevea trees on plantations in South America early in the present century. The disease spread from the scattered jungle trees to the planted areas and destroyed most of them. Thousands of acres were ruined and abandoned.

Following the initial failures, interest in rubber production in tropical America waned and support for a sustained effort to solve the leaf blight problem was long delayed. In the meantime, the world became dependent on Far Eastern sources for 97 percent of its crude rubber. There, in the absence of leaf blight, a thriving rubber-growing industry had been developed.

The first coordinated effort toward reestablishment of an appreciable portion of the rubber-producing industry closer to the great centers of consumption in the Western Hemisphere was initiated in 1940. Under the leadership of E. W. Brandes, the United States Department of Agriculture organized a project involving survey work, demonstration plantings, and study of disease problems. This project soon developed into a cooperative effort, with several commercial companies and the governments of most tropical American countries participating. The leaf blight problem received early attention in the cooperative program and two simultaneous attacks were launched against it. These were (1) selection of resistant clones, and (2) use of fungicidal sprays.

Selection of Resistant Clones

The blight-resistant clones that first entered into commercial use were selected on the Ford Plantations in Brazil. During the decade following the beginning of operations at Fordlandia in 1928, more than a million seedlings were planted. The bulk of the seeds came from the Tapajos River area of the Amazon Valley and produced no trees with high resistance to leaf blight. However, among smaller populations of trees originating from Belém and upriver seeds were dozens of individuals that were not damaged when leaf blight defoliated the adjacent trees. Another group of trees showing resistance to leaf blight came from budwood taken from outstanding jungle trees growing in the Acre Territory and the Rio Negro area of the Amazon Valley. The clones now referred to as the blight-resistant Ford clones (Fig. 1) were selected from these groups of material.

With the inauguration of the cooperative program of rubber investigations in 1940, the search for superior blight-resistant material was greatly expanded. Plant scientists were dispatched to Brazil, Colombia, and Peru. There they worked jointly with local scientists in studying the Hevea populations of remote parts of the Amazon Valley. Budwood and seeds were collected from superior trees and established in nursery centers. Hundreds of blight-resistant selections were obtained from these groups of material.

Even before the initiation of the cooperative rubber program, the Goodyear Rubber Plantations Company had initiated a search for blight-resistant material among clones and seedlings of Far Eastern origin. With the entrance of the United States Department of Agriculture into the cooperative program, more than a million seeds were obtained from the Philippine Islands and Africa and were tested in cooperative nurseries in Brazil, Costa Rica, and Panama. If blight-resistant clones could be obtained from this select population, the time-consuming process of cross breeding to combine high yield and disease resistance would be avoided.

The selection work with Eastern material soon demonstrated the need for a quick test to determine the degree of resistance or susceptibility to leaf blight. It was found that many plants that forged ahead in seedling nurseries (with the susceptible young foliage of their growing points above the level at which it could be subjected to the great mass of water-borne inoculum) later proved to have no appreciable resistance to leaf blight. Field plantings, likewise, were found to provide no reliable indication of blight resistance until the trees reached

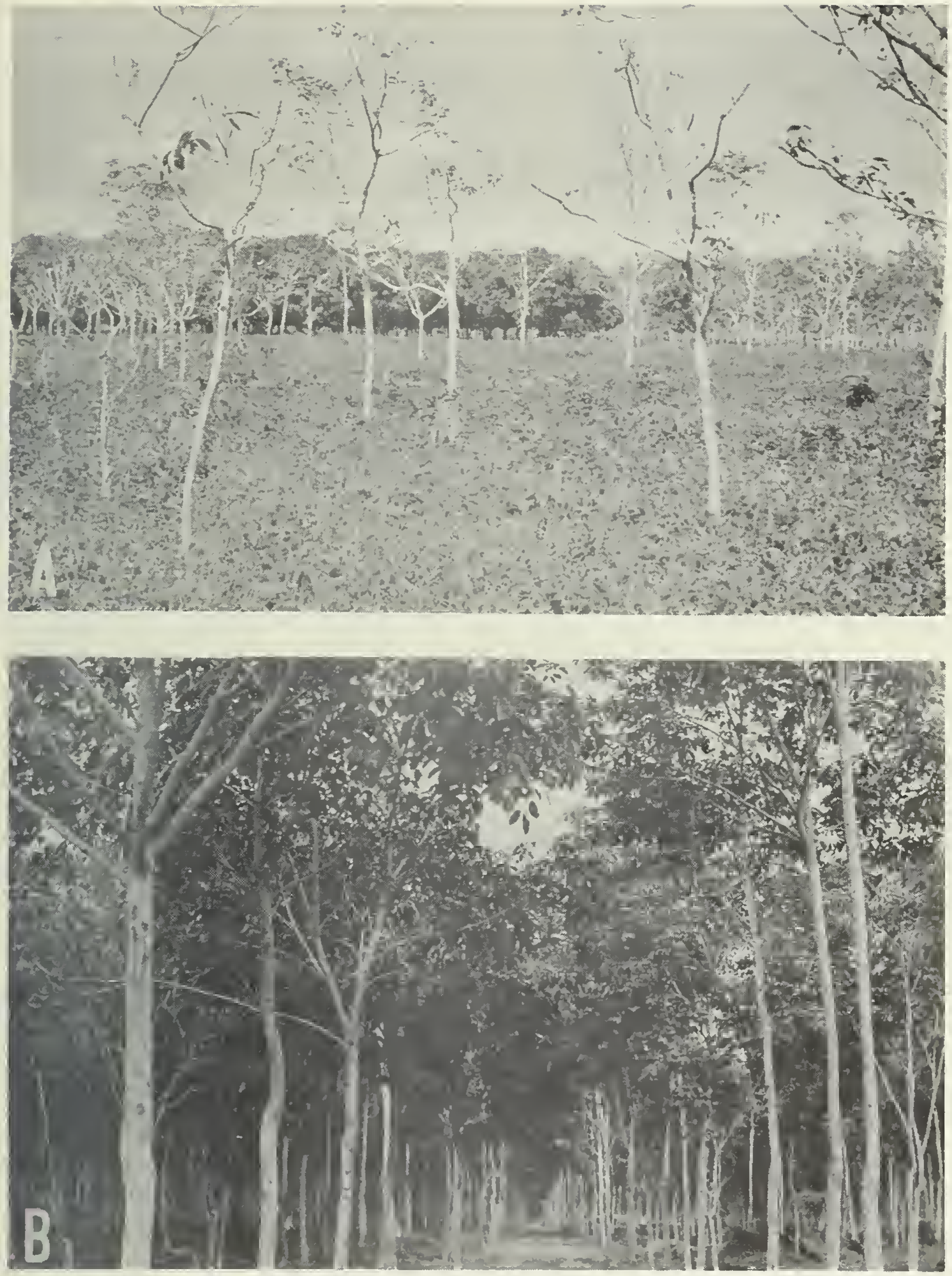

FIGURE 1. Hevea trees growing on a plantation in Brazil: A, Eastern clones; B, Eastern clones top-budded with blight-resistant clones.

the age of four or five years. By that time, the quantity of foliage and inoculum has multiplied many times over, thereby greatly increasing the opportunities for spore dissemination from leaf to leaf and from plant to plant. Thousands of acres of Hevea trees that escaped severe damage for several years were destroyed by leaf blight before reaching maturity. Development of a satisfactory test for resistance was one of the first problems on which pathologists of the United States Department of Agriculture focused attention.

Experiments carried out in Costa Rica in 1942 demonstrated that exposure in special nursery test plots was fully as effective as artificial inoculations, or exposure in moist chambers, in determining the degree of susceptibility or resistance of Hevea clones. A standard testing method whereby experimental clones or seedlings are grown in close proximity to heavily diseased plants through at least one rainy season was adopted. In an area offering favorable conditions for blight development, susceptible seedlings are planted on every third or fourth nursery row and may be protected by applications of fungicidal sprays until they are a few feet tall. Test clones are then planted on the remaining rows and, with spraying discontinued, they are subjected to a constant rain of inoculum. Clones demonstrating high resistance under this test have held up in all field plantings. Many of these were used in plantings that have now been brought into production.

Applying the resistance test described above, it was found that even the most tolerant selections from approximately 1,000 Eastern clones and more than 1,000,000 seedlings of Eastern origin went down under attack by leaf blight. A number of Ford clones and many selections from seedling populations from the Acre, Belém, and Leticia areas of the Amazon Valley demonstrated high resistance but offered little prospect of high yields. Neither the high-yielding Eastern clones nor the blight-resistant Amazon Valley selections alone could provide the planting material for establishment of a competitive, self-sustaining, rubber-growing industry. The two groups of material would have to be used jointly through a bud-grafting procedure until a third group of material, combining high yield with blight resistance, could be created by a breeding program. In the meantime, the blight-susceptible material would need protection in many areas.

Control with Fungicides

Effective control of leaf blight by fungicidal sprays had been demonstrated within a year after the cooperative program of the Division (now Section) of Rubber Plant Investigations was initiated. Among the copper, sulfur, and organic fungicides tested in Panama and Costa Rica during 1940 and 1941, the insoluble coppers proved most practical. Spreaders and stickers increased the efficiency of all spray mixtures. Under rainy-season conditions, the frequency of applications required for good disease control varied from semiweekly to weekly in most localities.

Numerous new fungicides were tested against leaf blight during the decade following adoption of the insoluble coppers as the standard spray material for use against the disease. None proved superior to the insoluble coppers until zinc ethylene bisdithiocarbamate (sold under the trade names Dithane Z-78 and Parzate) was tested on Speedway Estate at Cairo, Costa Rica, in 1950. These tests demonstrated that applications of Dithane or Parzate at 8-day intervals gave more effective control of leaf blight than applications of copper fungicides at 4-day intervals. Tests in other areas have given similar results, and these fungicides are now recommended for general use in spraying Hevea nurseries in blight-infested areas of the Western Hemisphere.

Although it has been demonstrated that leaf blight can be controlled on producing trees by the use of fungicides, economic considerations usually make it necessary to limit spraying operations to nursery plants and very young plantation trees. Therefore, the procedure adopted for establishing high-yielding Hevea plantings in the Western Hemisphere involves temporary spraying followed by top-budding with blight-resistant clones.

Top Budding

Base budding to insure high-yielding trees has long been practiced on rubber plantations but, prior to 1940, top budding was used only on a few experimental trees. Successful fungicidal control of leaf blight in nurseries of blight-susceptible seedlings and on young trees of Eastern clones enabled adoption of top budding as a commercial practice. When required, nursery seedlings are sprayed until they can be base budded with high-yielding clones. These, in turn, are sprayed until they can be top budded at a height of approximately 6 feet with blight-

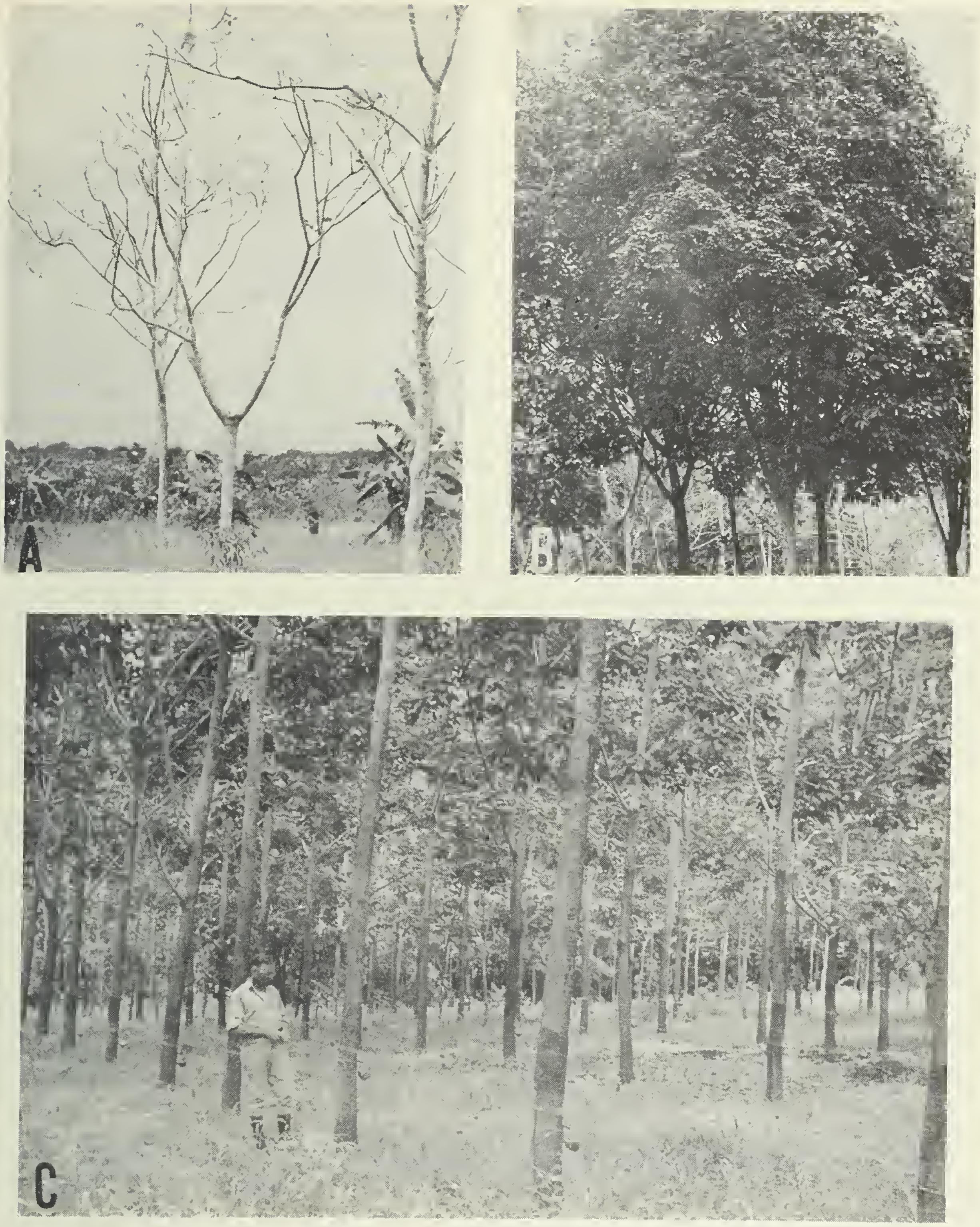

FIGURE 2. Typical representatives of the groups of material used in, and produced by, the Hevea breeding program; A, a high-yielding, blight-susceptible clone; B, a blight-resistant selection, and C, blight-resistant progeny of A X B.

resistant clones.

In addition to becoming the standard procedure used in establishment of high-yielding Hevea plantations in the Western Hemisphere, top budding saved many thousands of acres of Eastern clones planted in blight-infested areas during the period 1935 to 1940. In plantings where the bark was too old and brittle to permit budding, the trees were pollarded at a height of 6 or 7 feet and, when necessary, a new shoot was protected by spray applications until successfully budded.

It has become increasingly apparent that the growth of panel clones is determined to a large extent by the growth rate of the top clones with which they are budded. Whereas certain vigorous tops bring trees into production within four years under good growing conditions, other tops, which are equally resistant to leaf blight but slow growing, may require twice this amount of time. Thus, the opportunity to reduce the time required to bring trees to tapping size by selecting vigorous topbudding clones is apparent. Certain hybrid clones (progeny of Hevea brasiliensis X H. benthamiana crosses) are especially promising.

Breeding Program

A breeding program designed to produce plants combining high yield with disease resistance was inaugurated as soon as the cooperative rubber program got under way. The two radically different groups of Hevea clones which were available in the Western Hemisphere provided the required material. One consisted of the best-yielding selections from millions of trees growing in the Far East. These are susceptible to leaf blight. The other consisted of blight-resistant clones selected from large populations of seedling trees growing in South America. These have a low level of yield.

A large portion of the Hevea breeding work has been done at Belterra, Brazil, under the auspices of the Instituto Agronomico do Norte. Since 1944, this program has been directed by G. O. Addison, with assistance from the writers on agronomic and pathological phases of the program. Emphasis has been placed on making known crosses by means of hand pollination. High-yielding Eastern clones and blight-resistant indigenous selections have been used in a large majority of the crosses made to date.

More than 100,000 cross-pollination progenies have been produced and tested for resistance to leaf blight at Belterra. From these, approximately 8,000 blight-resistant plants have been selected and budded to the extent of five to ten field trees of each selection. The oldest of these clones are now undergoing yield tests.

A number of families of outstanding resistance and vigor have been produced by crossing certain highly resistant Ford clones with blight-susceptible Eastern clones (Fig. 2). The Hevea benthamiana clone F 4542 has given an especially noteworthy performance as a blight-resistant breeding clone. This clone was established at Belterra with budwood from a Rio Negro jungle tree and has proved immune to all populations of the leaf blight fungus to which it has been exposed.

A high percentage of the progenies from crosses between F 4542 and various Eastern clones has proved immune or highly resistant to leaf blight and many selections from these families have demonstrated exceptional vigor. Furthermore, a number of these selections, when back crossed to the high-yielding Eastern parent, have produced families in which more than 50 percent of the seedlings proved resistant to leaf blight.

Within each family produced by crossing a blight-resistant Ford clone with a susceptible Eastern clone, the plants range from highly susceptible to resistant. The percentage of resistant plants, however, varies greatly, depending on the Ford clone used in the cross. When moderately resistant clones are crossed with Eastern clones, the progenies are predominantly susceptible.

Only preliminary yield data have been obtained from clones derived from crosses between Ford and Eastern clones. It is obvious, however, that a large majority of the progenies of such crosses will, like the Ford clones, have a low level of yield. Under Belterra conditions, a very small percentage of the progenies tested has indicated yields which compare favorably with those of the Eastern clones.

From the large population of cross-pollination progenies tested to date, the following conclusions can be drawn:

(1) Certain blight-resistant clones, when crossed with susceptible clones, transmit high resistance to a majority of their progenies.

(2) Certain F_1 selections, when back crossed to the high-yielding susceptible

parent, have given more than 50 percent resistant progenies.

(3) Some blight-resistant selections have proved to be more vigorous than either parent.

(4) A very small percentage of the F_1 selections has indicated promising yields.

Specialization of the Fungus

Wide differences in the growth habit and yield of the Hevea brasiliensis populations of different parts of the Amazon Valley have long been noted and it was anticipated that differences in resistance to leaf blight might also occur. Since 1940, the Hevea populations of several widely separated areas have been studied. Some of these populations have shown a high level of resistance to leaf blight and others have shown extreme susceptibility. The most resistant populations generally occur in the upper part of the Amazon Valley. Those of the Acre Territory of Brazil, the Madre de Dios area of Peru, and the Leticia area of Colombia have been outstanding. The population occurring along the lower Tapajos River of Brazil (the area from which seeds were obtained to initiate the rubber-growing industry of the Far East) has proved extremely susceptible.

After striking differences in the level of resistance of the Hevea trees of different areas had been demonstrated, the pathogenicity of populations of the leaf blight fungus was studied. Wide differences in pathogenicity would make the results of resistance tests conducted in one locality invalid in other localities. Therefore, the fungus populations of rubber-growing centers extending from the State of Vera Cruz in Mexico to the Madre de Dios area of Peru were studied to determine their variability.

Through the cooperation of experiment stations and rubber-growing enterprises, groups of clones originating from the Belém, Tapajos, and Acre areas of the Amazon Valley were established in special test plots at Turrialba, Costa Rica; Port-of-Spain, Trinidad; Belém and Belterra, Brazil; and Tingo Maria, Yurac, and Iquitos, Peru. These clones were grown in alternate nursery beds with heavily diseased seedlings and were classified for resistance during the wettest part of one or more years. In addition to the tests on clonal material, seeds originating from many parts of the native habitat of the Hevea tree have been tested in strategic localities throughout tropical America.

A degree of specialization of the leaf blight fungus to the Hevea population that has long occurred in the same area with it usually exists. Specialization is especially pronounced in areas where a single strain of Hevea predominates. It may become less distinct after other strains of Hevea are introduced and cultivated over a period of years. In some cases, this change may be brought about by the rapid multiplication of hitherto minor components of the fungus population that are virulent on the new introductions. In other cases, however, the evidence indicates that the change occurs through the rise of a new and more virulent strain of the fungus.

In several localities, blight lesions have suddenly appeared on clones that previously had shown high resistance to leaf blight. When used to inoculate young leaf flushes of other plants of the same clone, the spores produced by these lesions have always shown greater virulence than spores taken from seedling plants growing in the area. Closely related clones, that is clones of the same origin or parentage, may also be more heavily attacked by this new strain of the fungus. In no case, however, has it proved more virulent to a wide range of components of the Hevea population.

A strain of the leaf blight fungus which appeared at Belterra, Brazil, in 1946 provides the most striking example yet recorded of the occurrence of a new physiologic race of the leaf blight fungus. On a number of Ford top-budding clones that had shown near immunity to leaf blight since 1939, numerous disease lesions began to develop in 1946. This strain of the fungus soon became established over the entire plantation but defoliation has not been heavy enough to cause serious damage to the affected clones. Insurance against extensive damage by new strains of the fungus is provided by using a mixture of resistant tops in commercial plantings of Hevea.

A second safety factor against the inroads of new strains of the fungus is provided by the diminishing chance of severe disease attack as Hevea plantings approach maturity. After the trees reach the age of seven or eight years, practically all new growth emerges during the annual leaf change period -- the driest and least favorable portion of the year for blight development. When this stage has been reached, the fungus often fails to maintain a supply of viable inoculum, especially on clones having a fair level of resistance. New foliage, therefore, emerges and passes through the young susceptible stage without being attacked.

Long Distance Spread of the Fungus

Spores of the leaf blight fungus may be disseminated by the wind. This method of dissemination doubtless accounts for a great majority of the cases of spread of leaf blight over long distances. The spore loads carried by air currents have been studied by exposing disease-free potted plants at graduated distances from blight-infested plantings. Additional information has been obtained by noting the initial occurrence and rate of spread of leaf blight in new Hevea plantings.

Studies on spore viability have shown that a small percentage of the spores resting on the dry surface of plant foliage, or stored in glass plates at room temperatures, retains the power to germinate and infect for a week or more. This enables viable spores to be carried hundreds, or even thousands, of miles in strong air currents.

Borne by the wind, leaf blight has moved into northern Colombia, Nicaragua, Guatemala, and a large number of hitherto disease-free localities in various countries since 1942. In anticipation of such spread, the program in the Western Hemisphere was planned on the assumption that all rubber-growing areas would eventually become blight infested. The time required for the disease to bridge the Pacific and establish itself in the great rubber-growing areas of the Far East is problematical. The material now available, however, provides the means for successful culture of Hevea rubber regardless of the presence of leaf blight.

Summary

Some of the early losses that attended the development of plantations in tropical America may be attributed to the failure to recognize the hazards of Dothidella ulei, the fungus that causes leaf blight. From experience and information acquired during those early attempts and intensive research, techniques have been developed that have brought South American leaf blight within the realm of control. Because resistance to leaf blight has been realized and effective fungicidal controls, where needed, have been proved, a definite goal in the rubber program has been attained. As far as this disease is concerned, it now is possible to place more emphasis on the genetic, agronomic, and horticultural aspects of rubber culture than on the pathological aspects.

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PHYTOPHTHORA LEAF FALL AND DIEBACK

W. E. Manis

Only recently has Phytophthora leaf fall and dieback on Hevea rubbertrees become a major disease problem in high-rainfall areas of Central America.

The devastating effects of the causal pathogen, Phytophthora palmivora, on Hevea have long been recognized in the monsoon regions of Burma and South India and in sections of Ceylon and Malaya. The disease occurs during the rainy season on the Belterra Estate in Brazil, but is arrested during the extended dry period.

Until late 1950, Phytophthora on Hevea (other than as a panel disease on the Speedway Estate in Costa Rica) was a minor disease at both the Cooperative Rubber Plant Field Station of the Department of Agriculture at Turrialba, Costa Rica, and at the substation, Los Diamantes.

A serious outbreak in 1950 was of particular interest where cacao pod rot, caused by the same organism, Phytophthora palmivora, abounds. Many cacao holdings adjoin Los Diamantes. The same general conditions exist near the Speedway Estate at Cairo.

No attempts at fungicidal control in those cacao plantings have been made. From the inception of the experimental work at Los Diamantes up to 1950, the incidence of Phytophthora damage to the rubbertrees was insignificant. Despite the nearby abundance of inoculum only an occasional nursery plant or a young field plant had been affected.

The causal agent, Phytophthora palmivora, unlike Dothidella ulei, which is responsible for the South American leaf blight, is not restricted to attacking young leaf and stem tissue. Phytophthora may infect mature leaves and petioles, green seed pods, green stem tissue, and bark, as well as immature leaves and branches.

One of the best diagnostic characters for the leaf-fall phase of the disease is a single petiole lesion, which in itself is enough to cause the leaf to drop. Mature leaflets may be attacked at any point, but the fungus most frequently enters at the base or the tip of the leaflets. Immature leaves wilt rapidly and turn dark, as though scalded. Succulent, developing branches are generally attacked about midway between the parent branch and the unfolding new leaves. From that type of infection, the fungus may move downward into the older branches and cause extensive dieback or kill the entire crown.

Development and perpetuation of Phytophthora in plantation rubber needs specific climatic conditions. Long periods of continuous rainfall, cloudy weather, and cool nights favor the fungus. Bright days and high temperatures arrest it and, if they last long enough, may check the disease. Therefore, the disease has not attained a ranking in importance equal to that of South American leaf blight, which has been responsible for retarding the spread of Hevea plantings in the Western Hemisphere.

In February of 1951, five months after the initial outbreak at Los Diamantes, Phytophthora leaf fall appeared at the Turrialba station and at the Speedway Estate. We do not assume that the disease was carried from Los Diamantes, some 40 miles from Turrialba and 18 miles from the Speedway Estate. The causal agent was present and needed only the proper impetus -- exact weather conditions -- to set it off.

Los Diamantes, in the Atlantic zone of Costa Rica, is at an elevation of 800 feet. The average annual rainfall is 176 inches. The average monthly rainfall varies from 7.12 inches minimum to 25 inches maximum; the lowest monthly total recorded is 1.64 inches and the highest is 51.58 inches. The longest dry period since 1942 was 22 days. Occasional dry periods of as much as ten days occur, but rainless periods mostly last two to five days. The temperature range is not great. Temperatures rarely are above 90° F or below 60°.

Weather during the last months of 1950 and the first half of 1951 favored the development and activity of the fungus on Hevea. Rainfall for the last three months of 1950 was above average. The prevalence of Phytophthora infection on cacao, manifested as pod rot, also indicates that climatic conditions in Atlantic Costa Rica must be at near the optimum point most of the year for this host-parasite relationship.

Phytophthora leaf fall was first observed at Los Diamantes on clone F 409, resistant to the South American leaf blight. The clone has been highly susceptible to Phytophthora at the Belterra Estate, but at Los Diamantes, about 150 trees had shown no predisposition to attack by Phytophthora palmivora despite the abundance of inoculum on the neighboring cacao plantings, and it was hoped that Phytophthora as a major disease might not affect local plantings.

This hope was shattered for trees at the Turrialba and Los Diamantes stations. After escaping the disease for 8 years, and at the Speedway Estate for 14 years, the trees were at-

tacked by a virulent epidemic, particularly at Los Diamantes, where trees were killed outright, or the crowns were greatly reduced with no opportunity of refoliation for six or seven months. At Turrialba, leaf fall continued for ten months.

Seed pods are regarded as the most susceptible part of the plant and diseased pods are generally considered responsible for the rapid dissemination of the disease in plantations. At the time of the initial outbreak at Los Diamantes most of the trees were not of seed-bearing age. Seeds produced on a few trees were quickly destroyed. This and subsequent outbreaks of epidemic proportions were sustained by the presence of active fungus in the cankered branches of infected plants.

Phytophthora spread rapidly from the eight-year-old trees of clone F 409 through 11 other leaf-blight-resistant clones in the same planting. All the clones are Hevea brasiliensis selections except F 6395, which is a seedling selection of a natural hybrid between H. brasiliensis and H. spruceana. It was the only clone in this planting that retained most of its mature leaves. The others were 95 to 100 percent defoliated, and had from mild to extreme dieback in the branches.

Of the 12 clones, three belong to a group recommended as standard blight-resistant top-working clones -- F 1620, FB 54, and FB 3363. Clone F 1620 was so severely infected that the cankers formed at the branch unions exuded sufficient latex to cause the ground cover directly below to become white. Clones FB 54 and FB 3363, although denuded, did not have as much dieback as did F 1620. The crowns of F 409 were 75 to 80 percent killed back. This clone had been excluded from the standard list of desirable top-working material because of its Phytophthora susceptibility in Brazil.

Besides the three clones designated above as standard top-working clones, two others, F 1619 and FB 3333, are in wide usage and have been budded extensively at Los Diamantes, where their complete susceptibility to Phytophthora has been shown. These five clones have been recommended on the basis of their behaviour in Brazil, where they have shown excellent leaf-blight resistance, good form, buddability, and no apparent damage from Phytophthora. The difference in infection at the different locations indicates that strains of Phytophthora palmivora exist on Hevea. From the severity of the infection at Los Diamantes, the Costa strain is more virulent than the strain at Belterra, Brazil.

The original outbreak at Los Diamantes occurred in an eight-year-old planting. From there the disease spread to the nearby nurseries and to both close and distant field plantings, which range in age from one to seven years.

Only the blight-susceptible, high-yielding Far Eastern clonal nurseries were under spray treatment when Phytophthora appeared. It was soon evident that all nurseries could be maintained only by fungicidal control. Dithane, the fungicide used so effectively against South American leaf blight, was used for Phytophthora control in the nurseries. As long as the plants could be sprayed once or twice weekly, depending on the amount and intensity of rainfall, the results were excellent. During periods of 10 days or more of continuous rain, spraying was impossible and the damage to both seedlings and budded nursery stock was great.

Varying degrees of tolerance to Phytophthora were observed among the different groups of seedlings in the nursery. Most damaged by Phytophthora were Hevea brasiliensis seedlings from the Madre de Dios region of Peru which possessed a high degree of resistance to South American leaf blight. Seedlings from clone F 1620 and other seedlings from mixed H. brasiliensis clones were highly susceptible to Phytophthora. Seedlings from the H. benthamiana clones F 4541 and F 4542 were highly tolerant of it. F 4542 exhibited a higher degree of tolerance than did F 4541. In the plants of F 4542 only the young leaves and new growth were attacked. Typical leaf fall of mature leaves was not observed. Stem lesions that occurred on the H. brasiliensis seedlings were not found on these two groups of benthamiana seedlings.

Clone F 4542, a jungle selection made by the Ford Plantations Company from the Rio Negro region in Brazil, because of its almost complete immunity to leaf blight has been used successfully and extensively as a resistant parent in the breeding program. This clone has shown a high level of resistance to Phytophthora in Brazil. At Los Diamantes, Costa Rica, on five-year-old tops of this clone, severe injury to immature leaf and stem tissue has occurred.. Leaf spotting on hardened leaves has been noted but neither typical leaf fall nor cankers in brown bark have been found.

Adjacent to the first Phytophthora-attacked area is an experimental planting containing eight trees each of 60 different leaf-blight-resistant selections. The experimental clones fall into three general classes: F_1 hybrids between high-yielding leaf-blight-susceptible Hevea brasiliensis clones of Far Eastern origin and blight-resistant H. benthamiana clones; F_1 progeny from blight-resistant and high-yielding H. brasiliensis clones; and blight-resistant H.

brasiliensis tops F 1619, F 1620, FB 54, FB 3363.

The top clones are budded in equal proportion over the entire area. Phytophthora spread through the planting with amazing rapidity. Only a few of the four-year-old trees were producing seeds at that time and, as would be expected, they were the first trees infected. As the disease progressed, defoliation and dieback continued until only a few plots of test trees remained healthy except for limited and restricted infections.

Three clones, IAN 45-586, IAN 45-605, and IAN 45-717, showed tolerance to Phytophthora leaf fall for over eight months. During that time they were bombarded constantly by quantities of inoculum from both sides, the inoculum being present in the twigs and branches of the control trees. Clone IAN 45-586 was bearing a seed crop in October, when Phytophthora appeared in the planting. The disease destroyed the seed pods, but leaf fall did not take place. In March of 1951, at a time when new growth was being put out, the succulent tips of this clone were injured but no dieback was observed below the last matured flush of leaves. On clone IAN 45-717 only a few young shoots were damaged.

One more clone showed some degree of tolerance, but typical Phytophthora leaf fall occurred to a limited extent. This clone, IAN 45-443, did not become denuded, as did the controls and the majority of the experimental clones. It is an F_1 progeny, having as parents H. brasiliensis clones F 409 and Tj 1. F 409 is a highly susceptible clone. Although IAN 45-443 holds its leaves well in older trees, the young plants in nursery areas are so susceptible to stem injury that multiplication of this clone is almost impossible unless it is maintained under spray.

In Brazil and Costa Rica, F 4537, a pure Hevea benthamiana clone, has shown a marked degree of susceptibility to branch dieback and stem cankers due to Phytophthora. Clone F 4542 is highly resistant to both. Progeny of F 4537, IAN 45-586, and IAN 45-605 developed stem and branch cankers during 1951-52, while IAN 45-717, with F 4542 as one of its parents, has remained free of cankers through January 1954.

The high degree of tolerance evidenced at Los Diamantes and also at Turrialba by clone IAN 45-717 under optimum conditions for fungus development cannot be attributed to chance escape. Annual girth measurements in the above-mentioned experiment were taken in March of 1951, 1952, and 1953. A correlation was observed between growth rate and degree of both defoliation and branch injury. The more severe the damage, the more retarded was the growth; the more tolerant the clone, the greater was the growth.

A 40-acre test planting at Los Diamantes has been top-budded with 28 selected leaf-blight-resistant clones to study the compatibility and the performance of these clones as tops on high-yielding Eastern clone panels. The tops are well replicated, budded in monoclone rows of 22 trees per plot. The north half of the area is top-worked with five standard blight-resistant tops, F 1619, F 1620, FB 54, FB 3363, and B 363, and two blight-resistant species tops, F 4542 (Hevea benthamiana), and F 5004 (H. guianensis). The south half of the planting is top-worked with 21 different selected experimental blight-resistant tops and F 1619 used as a control. The 21 experimental clones fall into two groups: 7 F_1 H. brasiliensis clonal crosses, and 14 F_1 hybrids, all with H. benthamiana F 4542 as one parent and a high-yielding H. brasiliensis as the other parent. In 12 of the hybrids, Tj 1 is the high-yielding parent and in the remaining two it is AVROS 363.

The oldest of the tops in this planting are five years old. The nearest other planting is 0.6 of a mile distant. Phytophthora first appeared in the south section of the planting on F 1619 tops in December 1950. The plots of this clone could readily be marked by their lack of leaves. The disease soon moved into the north section of the planting where defoliation and dieback on the standard tops and on F 5004 was severe. H. benthamiana F 4542 showed no typical leaf fall but tip injury did occur.

In the south section, only the control and some of the Hevea brasiliensis clonal crosses were heavily attacked. The contrast between the two sections of this planting was so striking that there can be no doubt of the presence of the resistance factors as contributed by the H. benthamiana clone F 4542. Some of the hybrid clones showed considerable tip injury, but none was defoliated as was the control, F 1619, in all of its 18 replications in the south half of the test during the 1950-51 epidemic. The more promising Phytophthora-tolerant clones, based on preliminary observation, were FX 469, FX 614, FX 645, and FX 649.

During late 1952 and early 1953 there was a shorter period of Phytophthora-favorable weather that was almost identical to that of 1950-51. The disease followed the same pattern of movement and defoliation through the planting. Observations in early 1953 confirm the four preliminary selections noted above, and clone FX 590 has shown up sufficiently well to warrant its inclusion in the promising group chosen from this 40-acre planting.

It was fortunate that we had a large number of blight-resistant IAN, FX, and F Brazilian clones in Costa Rica, where they have been subjected to a long-term, unplanned Phytophthora field test. The clones were distributed to the Costa Rica station through the cooperation of the Instituto Agronomico do Norte, Belém, Pará, Brazil.

Early in December 1950, at both Turrialba and Los Diamantes, young plants of the FX clones and F 4542 used in this compatibility test were inoculated with diseased tissue from freshly infected seed pods. Inoculations were made into the green bark between the second and third whorls of leaves below the growing shoot. All clones, including F 4542, gave a positive reaction to this type of inoculation. That Phytophthora developed in wounded tissue of each of the inoculated clones is no real indication that these clones might not have resisted normal infection of unbroken tissue; that is, entry of the fungus into mature leaves, petioles, or unwounded bark tissue. The presence or lack of some mechanical protection over the vulnerable plant parts may be an essential factor determining resistance or susceptibility to leaf fall. The glossy coriaceous type of leaf is found on most plants showing tolerance to Phytophthora.

The epiphytotics which occurred in Costa Rica in 1950 and 1951 and again in 1952 and 1953 were of extreme severity. The weather conditions responsible for their severity were of extreme nature. There is every indication that this may be repeated and that it may occur elsewhere. From these Phytophthora epidemics, intensive and extensive, has come a sounder basis for the continued studies on resistance to this disease in Hevea.

It has been shown that the standard top-working clones, F 1619, F 1620, FB 54, FB 3333, and FB 3363, can no longer be used in the Atlantic zone of Costa Rica, nor should they be used where similar climatic conditions prevail.

Tolerance, at a degree approaching resistance, has been found in some of the clones resistant to leaf blight. This valuable material is immediately available for top budding and, since it was brought to the fore under such severe conditions, carries with it the assurance needed for the continuation of successful plantation development in the vast potential rubber-producing areas of the Atlantic coast of Central America. Table 1 presents the Phytophthora-tolerant clones now recommended for Costa Rica by clone source.

Table 1. Hevea plants at Los Diamantes, Costa Rica, that showed a high degree of tolerance to Phytophthora leaf fall.

F_1 hybrids or clonal crosses	Cloned jungle selections	Clonal seedlings
IAN 45-717 (PB 86[a] X F 4542)	F 4542[b]	F 4542
FX 614 (F 4542 X Tj 1[a])	F 6395[c]	F 4541[b]
FX 469 (F 4542 X Tj 1[a])		
FX 645 (F 4542 X Tj 1[a])		
FX 649 (F 4542 X Tj 1[a])		
FX 590 (F 4542 X Tj 1[a])		
IAN 45-443 (Tj 1 X F 409[a])		

[a] *Hevea brasiliensis.*
[b] *H. benthamiana.*
[c] Natural hybrid between *H. spruceana* and *H. brasiliensis.*

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